2-1 Seatbelts on School Buses

Objectives:

1. To relate personal activities to studying distance, speed and time (114-6).
2. To defend a decision or judgement and demonstrate that relative arguments can arrive from different perspectives.
3. To construct arguments to support a decision or judgement, using examples and evidence and recognizing various perspectives (118-6).
4. To propose courses of action on social issues related to science and technology, taking into account an array of perspectives (118-10).
6. To analyze the benefits to society of applying scientific knowledge on motion and introduction of a particular technology (118-2).
7. To describe the relationship among speed, distance and time (NLS-2).

Introduction

The wheels on the bus go 'round and 'round
Should students on the bus, be belted down?

Every day millions of students ride a yellow bus to school. While students in Newfoundland and Labrador are required to buckle up in their own vehicles, this is not the case on the bus. In fact, most school buses are not even equipped with seatbelts. There has been a lot of debate as to whether seatbelts should be installed in school buses. A 10-year-old boy in Cape Breton, NS. wants to make seatbelts **mandatory** in school buses. Dylan Ross hurt his back on a school bus when the bus hit a bump jolting him up in the air and then crashing back to his seat. Ross believes that had he been wearing a seatbelt he may not have been injured. He collected 200 signatures on a petition and presented it to the mayor of his town. The town council agreed to ask the province to make seatbelts mandatory on school buses. Not everyone agrees however. It has been suggested that seatbelts might prevent students from exiting a bus in an emergency situation. In 2001 Transport Canada released a report stating that seatbelts have little or no effect on school bus safety (Boy, 10, lobbies for seatbelts on buses, 2004). Some feel that the issue of seatbelts is more a concern raised by parents then an issue based on safety and facts (Maritime bus safety consultation, 2000). What are those facts?

Theory

Arguments Against Seatbelts

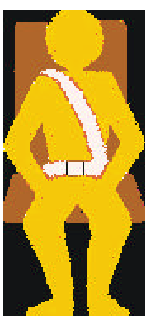
Experts have generally thought that the accident rate among bus passengers is so low, and the benefits of seatbelts so doubtful, that the expense of fitting seatbelts is not reasonable. In addition, school buses are required to meet more federal motor vehicle safety standards than any other type of motor vehicle. School buses are built with increased side impact protection barriers and reinforced roofs for rollover protection. Also, the large size of the bus and the ride height already provide a great level of safety for passengers. Since school buses are 8 to 10 times more massive than a typical vehicle, buses can absorb more energy in a crash without hurting passengers. Most injuries in large buses tend to be minor ones to the face and head resulting from hitting the tops of seat backs.

Installing padding can also prevent these types of injuries. It is much cheaper to install padding than to put seatbelts in buses. Cost of course is not important if children are at risk.

To reduce this risk, large buses mainly rely on compartmentalization to provide protection. This involves making changes to buses that create compartments meant to protect passengers during collisions. These changes include using seat backs that are higher, wider and thicker than in previous designs. Seats also have a steel inner structure that bends to help absorb energy. All metal surfaces are covered with energy absorbent padding. The seat is also required to be anchored to the floor strongly enough so that it cannot pull loose during a collision. Seat backs should also be spaced at a distance considered safe (typically 0.61 m) (Safety information: Seatbelts). Those in favor of seatbelts however, argue that this is not enough and that seatbelts offer added protection.

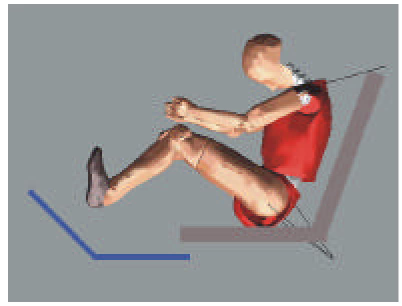
Arguments for Seatbelts

Every major medical association supports installing seatbelts on school buses (Seatbelt debate gains momentum, 2004). Some parent groups say that the idea of compartmentalization does not work in most bus accidents involving side impacts or rollovers. In these cases passengers do not always



remain completely within the seating compartment. During side impacts and rollovers children could hit their heads against the ceiling, floor or even other students. Children could be thrown against the side of the bus or even thrown out of the bus.

"During a crash, properly fastened safety belts distribute the forces of rapid **deceleration** over larger and stronger parts of the person's body, such as the chest, hips and shoulders" (Why safety belts, 2002). A seatbelt will stretch slightly to slow your body down and increase its **stopping distance**, thereby decreasing the force of impact.



(from Injury Evaluation Application – Crash)

In a collision an unbelted person will continue travelling at the vehicle's original speed. Newton discovered that an object in motion will remain in motion and an object at rest will remain at rest, unless some other force is applied to the object. When the vehicle stops, the person will continue moving and will hit the windshield or some other part of the car. They may even be thrown from the car. Unbelted passengers can also collide with each other.

Seatbelt supporters argue that seatbelts do not cause children to become trapped in buses. In 1998 a school bus carrying preschoolers, all wearing seatbelts, was struck sideways by a van and the bus rolled over. The children got out of their seatbelts and evacuated the bus safely before help even arrived. No one was injured. The police chief asserted that injuries would have been greater had seatbelts not been worn (Seatbelt debate gains momentum, 2004). Since wearing seatbelts has been shown to prevent injury, parents find it hard to accept that seatbelts are not offered on school buses. This is especially important in Newfoundland and Labrador where seatbelts are mandatory in regular vehicles.

Conclusion

Seatbelts or no seatbelts? As you can see the outcome of the debate surrounding this issue is important to students. In Newfoundland and Labrador the trend toward fewer schools means that in the future, more students will need to take the bus. It is important that students required to take the bus be as safe as they can possibly be. Some people might argue that because there are only a small number of accidents, school buses are safe without seatbelts. Others might argue that even one preventable injury is reason for change. What do you think?

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Questions

1. What are two arguments for and against the installation of seatbelts on school buses?
2. What is meant by compartmentalization? What arguments are given against compartmentalization?
3. How do seatbelts help protect passengers in a collision?
4. **Research:** Research the progress of school bus seatbelt legislation in the province of Newfoundland and Labrador.

Activities

1. Design a poster to convince someone that school buses should or should not have seatbelts.
2. Address the issue of seatbelts vs. no seatbelts in a class debate.
3. Place an object on a dynamics cart and roll it along the floor. Ask students to observe what happens to the object when the cart hits the wall. Construct a seatbelt for the object from a rubber band or a piece of string, and push the cart again. Ask students to observe the differences in the two situations.
4. Conduct a survey of people travelling on your bus to find out how many students believe the school bus should have seatbelts. How many students feel safe without them? Present the results of your survey to your class.

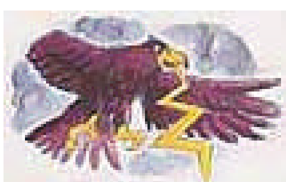
2-2 The Physics of Thunder and Lightning

Objectives:

1. To relate thunder and lightning to studying distance, speed and time (114-6).
2. To describe the relationship among speed, distance and time (NLS-2).
3. To solve three variable equations given any two values.
4. To describe quantitatively, and analyze mathematically, the relationship among distance, time and average speed of an object's linear motion (212-7, 325-1, 325-2).
5. To calculate any one of average speed, distance or time given the other two variables.
6. To explain what is meant by uniform motion.
7. To list the factors which affect the speed of an object.

Introduction

Have you ever experienced a thunder and lightning storm? While the loud booms of thunder and bright flashes of lightning can at times be frightening, they are also interesting to observe. Thunder and lightning have not always been as well understood as they are today. American Indians believed that thunder and lightning were caused by the sacred thunderbird. The thunderbird was believed to be a powerful spirit in the form of a bird. The lightning flashed from its beak and the thunder came from the flapping of its wings.



Ancient Greeks believed in the supreme ruler Zeus who had the all-powerful thunderbolt. Zeus had control over all the heavens and also controlled the weather and storms.

Today we know that thunderstorms occur when warm, moist air rises quickly to form clouds. Inside these clouds, water droplets and ice pellets rub against each other causing a build-up of **static electricity**. This results in a flow of electricity known as lightning - the most amazing element of a thunderstorm. Lightning actually causes thunder. When lightning strikes, the air around it gets very hot causing it to quickly expand. The expanding air causes a **shock wave** that turns into a booming sound wave commonly known as thunder. We can use the physics of light and sound to determine the distance to a lightning flash.

Theory

Sound and Light

Sound is a **longitudinal wave** that travels through air or some other substance like water. When a sound is created in air, the air particles vibrate or shake and they bump into one another causing the sound to travel through the air. A sound wave has a speed given by:

$$speed = \frac{distance}{time}$$

$$v = \frac{d}{t}$$

The faster a sound wave travels, the more distance it will cover in the same period of time. The following factors also affect the speed of sound:

i) The **phase** of matter. Sound waves will travel faster in a solid then in a liquid, and faster in a liquid then in a gas.

ii) Temperature. At normal **atmospheric pressure** the speed of sound in air is given by the equation,

$$v = 332m/s + (0.6\frac{m/s}{^{o}C})T$$

where T is the air temperature in degrees Celsius.

Using this formula we see that the speed of sound in air in a 21 °C room would be,

$v = 332m/s + (0.6\frac{m/s}{^{o}C})T$	• Start with the formula
$v = 332m/s + (0.6\frac{m/s}{^{o}C})21^{o}C$	• Put in the temperature
$v = 332m/s + 12.6m/s$	• Do the multiplication
$v = 345m/s$	• Do the addition
$v = 1242km/h$	

This may seem like a high speed in comparison to many of the speeds we observe on a daily basis. It is actually quite slow when compared to the speed of a light wave.

Light travels through the air at a speed of 300 000 000 m/s. Since this value is about 900 000 times the speed of sound, it is easy to understand why there is a delay between seeing lightning and hearing thunder during a thunderstorm. The light travels much faster and reaches us earlier than the slower sound.

Thunder and Lightning

When a lightning strike happens, we can see it almost right away because it is travelling so fast. The sound wave arrives later because it is travelling at a much slower speed. The distance to the location of the storm can be estimated by using this time delay between lightning and thunder. If, for example, the thunder is heard 4.0 s after the lightning is seen, then during that time, assuming a speed of 345 m/s, the sound has travelled,

$$\text{distance} = \text{speed x time}$$
$$\text{distance} = (345m/s)(4.0s)$$
$$\text{distance} = 1380m$$
$$\text{distance} = 1.4x10^{3}m \ \ or \ \ 1.4km$$

Using this formula we see that the storm is about 1.4 km away. If you count from when you see the lightning flash until you hear the thunder, each second equals about 344 m in distance. Another rule of thumb is that every three-second delay corresponds to a distance of about 1.0 km. If the thunder and lightning is very close by, the time delay may be too small to notice. We can determine whether a storm is moving toward or away from us by estimating the distance to several lightning flashes in a row. We can also get a general idea of how far away the lightning is by the type of thunder heard. Since sound bounces off air molecules, it travels in many different directions. The further away the source of the sound is the more it will be distorted. This means that if you hear rumbling thunder the lightning bolt is far away, but a loud crack of thunder means that the lightning bolt is closer to you (less than 100 m).

Conclusion

Thunder and lightning are happenings that people still find interesting today. We have come a long way in our understanding of thunder and lightning from something to be feared, to something that can be understood with some knowledge of physics. Like Zeus' mythical thunderbolt, our knowledge has 'taken the world by storm'.

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Questions

1. Tom is out jogging. He sees a flash of lighting and counts 6.0 seconds until the thunder is heard. How far away is the storm if the speed of sound is 344 m/s?
2. What is the speed of sound in a room where the air temperature is 19°C?
3. List and describe two factors that affect the speed of sound.
4. **Research:** Try to find other myths about the origin of thunder and lightning and present one to your class.

Activities

1. For a simulation of thunder, see http://sln.fi.edu/franklin/scientst/electric.html.
2. Research the origin of some common sayings, like “fast as lightning” or “greased lightning”.
3. Research some of the common misconceptions regarding lightning (eg. Lightning never strikes the same place twice)
4. Investigate how lightning rods protect buildings.
5. Investigate how aircraft survive lightning strikes.
6. Make thunder by blowing up a small paper bag and popping it. It makes a loud bang because the air inside the bag has expanded quickly, just as it does when heated by lightning.

2-3 The Physics of Hybrid Electric Cars

Objectives:

1. To list the factors which affect the speed of an object (NLS-2).
2. To relate personal activities to studying distance, speed and time (114-6).
3. To analyze the benefits to society of applying scientific knowledge on motion and introduction of a particular technology (118-2).
4. To propose a course of action on social issues related to science and technology taking into account human and environmental needs (118-9).
5. To propose courses of action on social issues related to science and technology taking into account an array of perspectives (118-10).
6. To construct arguments to support a decision or judgement, using examples and evidence and recognizing various perspectives (118-6).

Introduction

Purchasing a new vehicle is a big decision – a decision you may make in the near future. Most people want a vehicle that is comfortable, powerful and affordable. Consumers also look for good gas mileage – no one wants a **gas-guzzler**. Aside from the financial benefits, there are also environmental benefits with vehicles that use less fuel. Given that gasoline is a **non-renewable resource**, automobile manufacturers have realized the need to produce vehicles that are more efficient. The result has been the development of hybrid-electric cars: "half gas, half electric, half fuel use, half the emissions: the remarkable characteristics of the brand-new hybrid-electric car" (Burke, 2000, p. 30).

Theory

Background

The concept of a hybrid-electric car is not really brand-new. The first major types of horseless vehicles, designed at the beginning of the 20th century, included the gasoline-electric vehicle, the electric vehicle and the steam powered vehicle. In 1912 Henry Ford developed the first electric car for his wife Clara. The electric vehicle could not travel as far as other types. The first hybrid-electric vehicle appeared in Philadelphia as early as 1897. Hybrid-electric cars were built to combine the benefits of electricity and gasoline, by

Toyota Prius

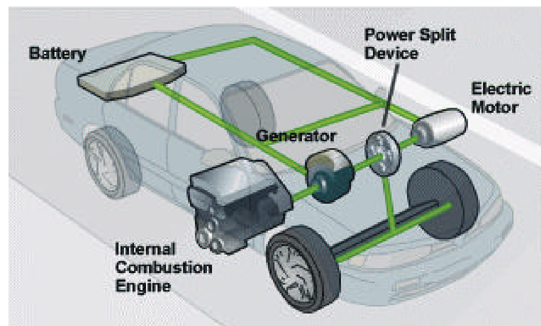
increasing the travelling distance and improving efficiency. In those days, one of the big benefits of the hybrid-electric motor was reliability. If the gas engine wouldn't start the electric motor would get you home. Unfortunately this first model went up in flames when the designer caught his foot on a wire, sending a spark of current to the gas tank. The gasoline-only engine was chosen over the other types even though it was only about 20% efficient in converting energy into motion. At the time, gasoline was easy to get and inexpensive. This is no longer the case.

Since Earth now supports around 600 million vehicles and gasoline is an expensive and non-renewable energy source, we can no longer ignore the low efficiency of the gasoline engine. The trend towards hybrid-electric vehicles has been in response to environmental concerns like air pollution and shrinking petroleum deposits. A purely electric car that does not release emissions is good for the environment. It is also about 90% efficient, but cannot travel long distances. Most people need a car that can make long trips. A combination of the electric engine and gasoline motor in the form of the hybrid-electric car is a good alternative.

The Hybrid-Electric Vehicle (HEV)

In a hybrid-electric vehicle either the gasoline engine or the electric motor is used to provide power to the wheels. The presence of the gasoline and electric components allows the car to match the driving conditions to the best source of energy. The HEV can turn the engine and the motor on and off as long as one of them is powering the car. The gasoline engine is normally used for cruising and long trips that require high energy. The electric motor is used in situations involving slow speeds or those requiring high power, like starting or climbing hills. If used, the gasoline engine would use more fuel and release more emissions during these high power situations. The HEV actually prevents the gasoline engine from operating in these situations and thereby reduces the largest amount of emissions.

The HEV also charges its own batteries. Energy not needed to drive the car can be stored in the battery and saved for later. During braking in regular gasoline engine cars, the energy from the forward motion of the car is turned to heat in the brakes. In the HEV this energy is not lost as heat, but is stored in the battery for later use. Batteries in a HEV are smaller than batteries in a purely electric vehicle. HEV batteries only need to store the amount of energy needed for high power situations. The engine is also smaller because it does not have to provide as much horsepower, making it more fuel-efficient.



Cost

Several manufacturers have experimented with hybrids. In 1997 Toyota became the first automaker to mass-produce a hybrid vehicle. The first hybrid available for sale in North America was offered by Honda in 1999 (Hybrid Motors). These vehicles cost anywhere from $1800-$5000 (Canadian) more than comparable gasoline engine cars. You will get better gas mileage, but it may be difficult to make up these extra costs. To drive 24000 km with a Honda Civic hybrid you will need about 1234 litres of gas. At 1.00 dollar per litre the yearly fuel costs would be about $1234. To drive 24000 km with a gasoline engine Honda Civic LX, you will need about 1719 litres of gas. At 1.00 dollar per litre the yearly cost is about $1719, just $485 more than the hybrid. After five years of this you would save $2425. That is still a long way from the extra money you paid to purchase the HEV. Increasing gasoline prices, however, may make an HEV more economical. “Helping the earth can be hard on your wallet” (Lazarony, 2003).

In the US there are tax deductions for buying a hybrid vehicle that will help offset these costs. In the UK even the Queen had her fleet of Rolls Royces converted to low emissions vehicles. In Canada the response is slower but things are happening. The British Columbia provincial government offers a tax break of up to $2000 to new owners of hybrid vehicles (Lightburn). Consumers in all provinces get a $100 discount ($500 in BC) off the before-tax purchase price of a hybrid vehicle.

Though financial savings are important, many consumers buy hybrid vehicles to help the environment. Industry experts expect hybrid sales to increase rapidly in the next few years, as gas prices increase and as more types of hybrid vehicles become available.

Conclusion

Electric vehicles while highly efficient, do not have the travel range required by most drivers. Gasoline engine vehicles, though widely used, are extremely inefficient and environmentally unfriendly. Some automakers are exploring **fuel-cell** technology for their electric cars. Fuel cells would use an on-board fuel processor to convert gasoline to water, carbon dioxide and hydrogen that will then be used to create electricity to power the vehicle. Fuel cells would deliver the same travelling distance as gasoline vehicles and could greatly improve fuel economy. In April 2005, the first factory-produced hydrogen fuel cell vehicles for public use (Ford Focus fuel cell vehicles) were delivered to Vancouver. These will be test driven by various groups over the next three years (Davis, 2005). There are still a number of problems with fuel cell technology including cost and design problems. Currently, there is no price tag on the fuel cell vehicles, but experts estimate it would be in the $100 000 range. Once all the glitches are ironed out, fuel cell technology could revolutionize the automobile industry. Currently though the hybrid-electric vehicle may provide the best balance between cost, environmental considerations and performance required by consumers.

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Questions

1. What is a hybrid-electric vehicle?
2. List one disadvantage for the electric motor vehicle and for the gasoline engine vehicle.
3. In the hybrid-electric vehicle, why is the electric motor used in situations requiring high power?

4. **Research:** What are the most recent figures for the number of hybrid-electric vehicles sold in Canada?
5. **Research:** What models of hybrid-electric vehicles are currently available to consumers?

Activities

1. Imagine you are an automobile manufacturer. Given the higher costs of hybrid-electric vehicles, how would you promote your product to consumers?
2. Design a poster comparing conventional gasoline engine vehicles with hybrid-electric vehicles in terms of cost, fuel efficiency, and environmental considerations.
3. For a simulation of how the HEV operates under different driving conditions see: http://www.toyota.com/vehicles/2005/prius/key_features/hybrid_syn_drive.html.

2-4 The Physics of the Olympics

Objectives:

1. To relate the Olympics to studying distance, speed and time (114-6).
2. To analyze the benefits to society of applying scientific knowledge on motion and introduction of a particular technology (118-2).
3. To propose courses of action on social issues related to science and technology taking into account an array of perspectives (118-10).
4. To construct arguments to support a decision or judgement, using examples and evidence and recognizing various perspectives (118-6).
5. To describe the relationship among speed, distance and time (NLS-2).
6. To solve three-variable equations given any two values.
7. To explain what is meant by uniform motion (214-3).
8. To list the factors which affect the speed of an object.

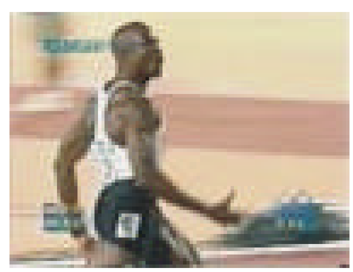
Introduction

"The modern Olympic games were founded by Baron Pierre de Coubertin in 1896, with the intention of improving health and education, promoting world peace, and encouraging fair and equal competition" (Haake, 2000). While today's Olympic sports promote many of these goals, there is some argument about "fair and equal competition". It has been suggested that modern advances in equipment design may give some athletes an unfair advantage, especially if the technology is not available to everyone. The amount of unfair advantage also depends on the sport itself. This article will discuss the physics of three Olympic events, speed skating, swimming and the 100-metre sprint. It will focus on how technology has affected the development of each sport.

Theory

100-metre Sprint

It was a proud moment for Canadians when Donovan Bailey won the 100-metre sprint gold medal at the 1996 Olympics in Atlanta.



In the 100-metre sprint, competitors accelerate out of the **starting blocks** to run 100 metres in the shortest time possible. Sprinters start from a crouching position and push against the starting blocks to help them accelerate. The average speed for a runner can be calculated using,

$$v = \frac{distance}{time}$$

$$v = \frac{d}{t}$$

where v is the average speed in m/s, d is the distance in meters (100 m), and t is the time in seconds. Around 1995 a new **starting block** was developed. It allowed the measurement of a **false start** to within 0.10 s of the firing of the starting gun. Technology has also been important in the timing devices for the race. These days, the difference between winning and losing is so small that timing devices must be extremely accurate. "Today's timing systems usually consist of a clock, which is triggered by the starter's gun, a light source, and an optical pick up device that stops the timer when the winning athlete cuts the light beam" (Haake, 2000). This timing device must be accurate to within 1/1000th of a second (0.001 s) for the 100-metre sprint. This means that someone running the race in 9.838 s would lose the race to someone running the race in 9.837 s. If the timer could only read 9.8 s we would not be able to determine a winner in this case.

Technology for the sprinters themselves is mainly in the form of better running shoes and improvements to the surface of the track. Information from past Olympics for the 100-metre sprint show that improvements in race times are now only about 0.006 s per year compared to 0.015 s per year a century ago (Haake, 2000). Given this information it is likely that technology plays a relatively small role in the 100-metre sprint. This is not the case however for swimming, where developments in technology have had a large impact on the sport.

Swimming

A big technological advance in swimming has been the design of a swimsuit fabric called "Fastskin". Invented by marine biologists it was designed to move water away from its surface similar to that of a shark's skin. Speedo, the developers of Fastskin, claims that by reducing drag (the force opposing the forward motion of the swimmer), this material can reduce a swimmer's time by up to 3%. This may not seem like much, but in a sport where one tenth of a second (0.10 s) is important, it can make a huge difference. Many of today's top athletes believe that wearing these suits can make a difference in how well they swim. Ian Thorpe wore a bodysuit while setting three world records

Swimmers Matt Dunn, Susie O'Neill and Michael Klim (R) model the suit

at the Australian Olympic trials in May 2000 (If the Suit Fits, 2000). Swimmers have generally found that the more skin they cover the more quickly they can swim. So

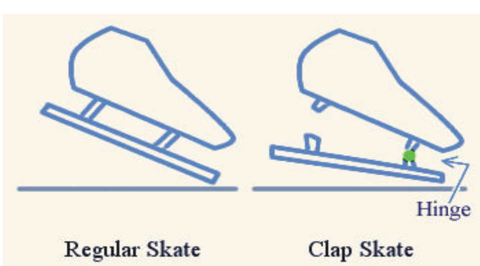
swimmers are beginning to wear suits that cover more of their bodies. Bodysuits are available in several styles. One style covers from the neck down to the ankles and wrists. Some suits leave the arms exposed and end at either the knees or ankles, while others cover only from the waist to the knees.

The new swimwear and its record-breaking results, has raised the question of whether technology is overtaking an athlete's ability. The world governing body of swimming ruled that Fastskin bodysuits do not make swimmers any faster or more **buoyant**, so they can be worn during international competitions (Olympic Swimmers Well-Suited, 2000). Even though the suits have not been proven to help, swimmers are still wearing them. The athletes say that swimming is a mental sport and if wearing a bodysuit makes them feel better during a race they should wear one. Whatever the reason, many world records have fallen to athletes wearing some form of bodysuit.

Mark Schubert, coach of the US men's swim team for the Sydney 2000 Olympics, believes that the technology should be controlled but not banned (If the Suit Fits, 2000). He feels that as long as everyone has the chance to wear the same types of suits there should not be a problem. Others would say that using these suits give some athletes an unfair advantage. The newest model of bodysuit was banned from the August 2000 US Olympic trials because there was concern that not all of the 1300 swimmers would be able to get one. Swimming and sprinting are not the only Olympic sports that have been affected by technology. Speed skaters have faced a similar situation.

Speed skating

Technology has had an big impact on speed skating, in the form of the clap skate first used at the Nagano 1998 Winter Olympics.



The clap skate got its name from the clapping sound made when the blade snaps to the skate. It has a spring-loaded hinge that allows the ankle to be raised from the blade.

The blade can therefore stay on the ice a little longer than with a normal skate. In speed skating this can be a big advantage. The design allows the entire blade to remain in contact with the ice for a slightly longer period each push. Skaters can get more force behind each push making them faster.

Athletes using the clap skate had to adjust to this technology by learning how to push off with their toes instead of their ankles. It looks like these skates really work. Five world records were broken at the Nagano Olympics. The clap skate quickly became very popular for speed skaters. A spokesman for the US speed skating team stated that "once everybody got used to the advantage of them…there was no more controversy" (If the Suit Fits, 2000).

Conclusion

The topics discussed here highlight the impact that technology has had on Olympic sport. In the 100-metre sprint, it seems that technology has played a minor role. Most important is the strength and power of the athlete. Performance in swimming is different. It seems to have improved with the introduction of new swimsuits. This has caused controversy in the sport. In speed skating, performance improved with the use of the clap skate. The athletes' ability to adapt to the new equipment was also responsible for these improvements. Is using the available technology the same as cheating? As long as all competitors have equal access to technological advances, it is the skill of the athlete that is most important. In this way the Olympic goal of "fair and equal competition" can still be realized in modern times.

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Questions

1. A women's 50 m back stroke is completed in 29 seconds. If the athlete was wearing a Faskskin suit, what improvement should she expect to see in this time?
2. Why is it so important to have accurate timing devices for the 100-meter sprint?
3. What is your view on the use of bodysuits in Olympic swimming? Should they be permitted?
4. Donovan Bailey completed the 100-metre sprint in 9.84 s. What was his average speed for the race?
5. **Research:** How has technology affected your favourite sport?

Activities

1. Time some of your classmates doing the 100-metre sprint. Experiment with changing the type of footwear or the track surface used and compare the times. Calculate the average speed of each runner under the different circumstances and graph their motion.

2-5 The Physics of Animal Tracking

Objectives:

1. To describe the relationship among speed, distance and time (NLS-2).
2. To analyze the benefits to society of applying scientific knowledge on motion and introduction of a particular technology (118-2).
3. To relate animal tracking to studying distance, speed and time (114-6).
4. To solve three variable equations given any two values.
5. To describe quantitatively, and analyze mathematically, the relationship among distance, time and average speed of an object's linear motion (212-7, 325-1, 325-2).
6. To calculate any one of average speed, distance or time given the other two variables.

Introduction

Have you ever had the unfortunate experience of losing your pet? Perhaps your house cat snuck out through the open window, or your dog got lost in the park. Some are lucky enough to have their pets return on their own after a few days. If the pet had a nametag perhaps someone returned it to your home. For many pets and owners there is no happy ending. According to the American Humane Association (Eisenberg, 2004) only a small percentage of animals are reunited with their owners. Technology however, can help ensure that owners will be able to find their animals.

Theory

Radio Telemetry and Microchips

The first big breakthrough in tracking technology happened in the early 1960's with the use of radio telemetry in tracking wildlife. Radio telemeters consist of a **transmitter**, an **antenna** and a **power cell** that are attached to the animal. For large animals a harness or a collar is the most common method for attaching the transmitter. Most collars have a standard **signal range** of 3.3 - 14.5 km. In clear open country the distance may be even greater. Small animals like pets must be fitted with tiny transmitters that are not too heavy. The signals that are emitted by the transmitters are then picked up by receivers. The antenna helps to magnify the signal coming from the animal's transmitter. The animal can then be found by following the signal. For a pet, the owner would press a button and the device on the pet's collar would emit a sound to alert the owner to the pet's location.

This kind of tracking has also been used to find children. At Hyland Hills Water World near Denver (the biggest water park in the United States) watch-like tracking devices have been rented to help parents keep track of their children. The device rents for between $2-3 US a day and sends out signals every eight seconds that are unique to each of the watches (Pigg, 2000). Fourteen antennas around the park then pick up these signals and a computer determines where a child is on the ground. Parents can use one of six scanners on the park grounds to locate their child. One disadvantage of these watches is that the child can remove them. Microchip technology takes care of this problem – at least for pets.

Pets can also be located using **microchips**. Implanted microchips are about the size of a small grain of rice and have a unique identification number that cannot be changed but can be read by a radio scanner. This number is then matched to a **database** to find the pet's owner (as long as the owner has registered with the database). In the United States a national database is maintained in Raleigh, North Carolina.

Global Positioning System (GPS)

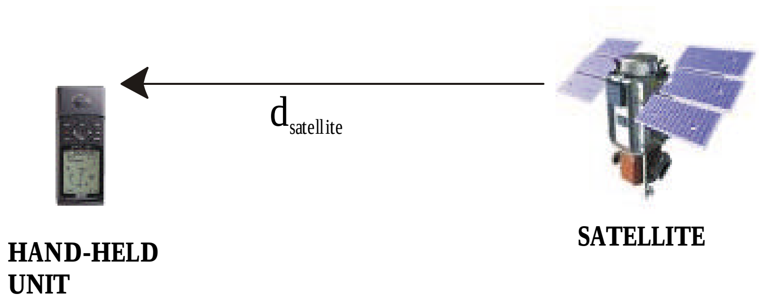
Another type of tracking device uses the **satellite** global positioning system (GPS). The global positioning system is a space satellite-based navigation system consisting of a network of 24 satellites that are orbiting Earth at a height of about 18 000 km. There are actually more than 24 orbiting satellites, as additional satellites are placed in orbit to replace those that break down. The satellites are always moving, making two complete orbits around the Earth every 24 hours. GPS is a navigation system that allows users to determine their location anywhere on Earth to within 15 m or less. Radio signals travelling at the speed of light (300 000 000 m/s) are timed as they travel from the satellite to the hand held unit and back to the satellite. Each GPS satellite carries a highly accurate clock whose time is constantly transmitted to the ground by radio waves. The distance between the satellite and the user can then be calculated using,

$$distance = speed \quad x \quad time$$

$$d_{satellite} = (\,300000000\, m/s\,)\, x\, (\,t\,)$$

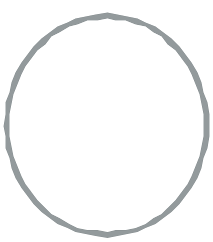
where $d_{satellite}$ is the distance between the satellite and the user, and t is the time for the signal to go from the satellite to Earth and back again. We must divide by 2 to get the distance from Earth to the satellite.

$$d_{satellite} = \frac{(300000000 m/s)t}{2}$$



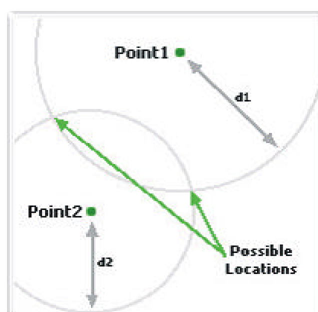
The time given is for the signal to go to the hand-held unit and come back to the satellite. We must divide by 2 to get the one-way distance.

Receivers on Earth can communicate with at least five GPS satellites at any one time. A measurement using one satellite can locate an object somewhere on a circle.



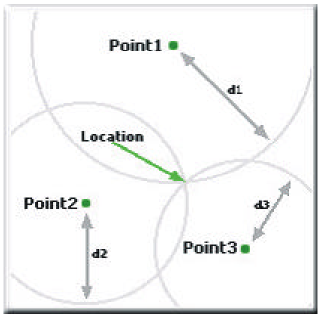
With one satellite the object can be located anywhere on the radius of this circle.

A second satellite can locate the object on another circle. The place where these two circles overlap gives two possible locations for the object.



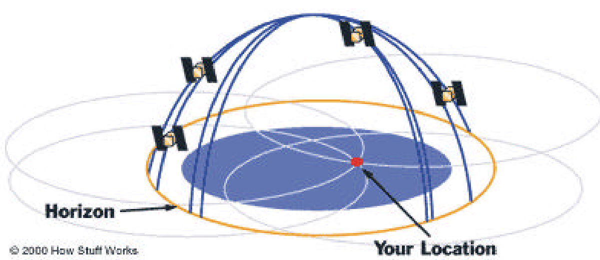
This figure shows two known positions indicated by point 1 and point 2 in the diagram. The circles show all points at known distances d1 and d2 from them. These are the data that the GPS receives from the orbiting satellites. There are two possible locations that are the specified distances from the two locations. These are shown by the points where the two circles overlap.

A third satellite establishes a third circle that crosses the other two providing the exact location of the object. So on a flat surface, three sets of location and distance information are required to uniquely identify a point in space.



This figure shows an additional point 3 and all positions a known distance d3 from it. This additional information allows us to identify a single location on the page.

In three-dimensional spaces such as the one in which we live, things become a little more complicated. In this situation four sets of positions and distances are required to uniquely identify a location.



Using GPS technology, pet owners can keep track of their dogs using miniature GPS receivers attached to the dog's collars. One such system, Global Pet Finder, has been invented by GPS Tracks in New York. If the pet leaves its yard the owner will get a call on their phone or cell phone (Eisenberg, 2004). Pet locations will be identified by street name and number, or by maps for some cell phones. Where there are no street signs, owners will be given directions from where they are located.

Conclusion

Technology is very important in animal tracking for wild animals and more recently, for pets. It will be extremely useful in helping to reunite pets with their owners. With a little help from physics and technology, Fido need never get lost again!

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Questions

1. What is the Global Positioning System (GPS)?
2. It takes a satellite signal 1.2×10^{-4} s to travel from the satellite to Earth and back again. What is the distance between the satellite and Earth?
3. Why is it necessary to have at least three satellites to determine a location on Earth?
4. **Research:** What are some other uses for GPS technology?

Activities

1. Become familiar with a hand held GPS unit and set up a special treasure hunt in your community in which your classmates can participate. This activity is based on the GO TO function of the GPS unit. Ensure that your participants know how to operate this function.
   a) Locate and mark 4-6 sites in the community or school. Each site should be easily accessible by foot or car.
   b) Create a "passport" for your searchers. They will need it to validate that they have found each waypoint.
   c) Each site should have some sort of validation tool. This could be a sticker or a stamp pad. When your "hunters" find the point, they can mark their "passports."
   d) Set a starting point (e.g., your school). You will need to give your participants a brief set of instruction on what they are to do. This will include where they are to go when they have completed the "hunt."

Source: http://www.lewiston.k12.id.us/SBranting/dead/gps.htm

2. For another tracking activity with detailed instructions and worksheets, see

   http://www.chicos.caltech.edu/classroom/GPS/GPSActivity1.pdf or

   http://www.chicos.caltech.edu/classroom/GPS/GPSActivity2.pdf

2-6 The Physics of Space Shuttle Launch

Objectives:

1. To analyze the benefits to society of applying scientific knowledge on motion and introduction of a particular technology (118-2).
2. To propose a course of action on social issues related to the Space Shuttle taking into account human and environmental needs (118-9).
3. To propose courses of action on social issues related to the Space Shuttle taking into account an array of perspectives (118-10)
4. To construct arguments to support a decision or judgement, using examples and evidence and recognizing various perspectives (118-6).

Introduction

Imagine yourself as an astronaut preparing for a launch into space. You are strapped into your seat in the shuttle wearing your space suit with an attached helmet and visor. You have been sitting here for at least three hours waiting for the launch. Three hours is nothing though, compared to the years of study and training it took to get here. The moment you have been waiting for is finally about to happen. Ten, nine, eight, seven, six, five, four, three, two, one…blast off! Nearly every child dreams, at one time or another, of becoming an astronaut. Making this dream happen requires a lot of hard work and training as well as knowledge of physics.

Theory

Background

To become an astronaut, you must either be a test pilot, a scientist or an engineer. Candidates have usually done very well in one of these jobs before they become astronauts. Astronauts are selected about every two years. Out of approximately four thousand applicants, only about twenty are accepted at one time (Astronaut Training, 2004). For the first year after selection, you are considered an astronaut candidate. After one full year of school and basic training, you are considered a 'real' astronaut. Astronauts continue taking classes and training while they are waiting to be assigned to a flight. Once assigned to a flight they then start more mission-specific training with other members of their flight team. Astronauts must study many different types of science that will be done onboard the shuttle. They complete experiments in space that are designed by scientists on Earth. One area of study is how things work in a low gravity situation.

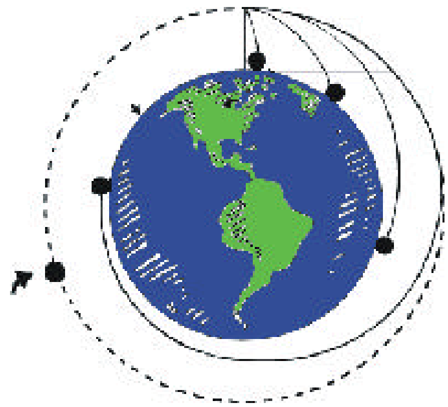
Science

On Earth our bodies are accustomed to a **gravitational field** of 9.8 m/s^2. This means that if you drop an object on Earth it will accelerate downward at a rate of 9.8 m/s^2. For every second the object falls, its speed will increase by 9.8 m/s. This value of 9.8 m/s^2 is known as the acceleration due to gravity (g). In the absence of **air resistance** all objects, regardless of mass, would drop at the same rate of 9.8 m/s^2. If you were to drop a feather and a golf ball in a **vacuum**, they would both hit the ground at the same time. When air resistance is involved however, we know that the golf ball will hit the ground first.

In space these ideas about gravity change dramatically. On other planets or on the moon, the value of acceleration due to gravity changes. This is because the mass and size of the moon or some other planet is different than the mass and size of Earth. On the moon for example, gravity is only 1.62 m/s^2. When we see pictures of astronauts on the moon, they appear to be floating and bouncing. This is because gravity is so much less. The following table shows the values of acceleration due to gravity on the surfaces of some other planets:

Place	**g(m/s^2)**
Mercury	3.61
Mars	3.75
Venus	8.83

When astronauts are in the space shuttle they are in a low gravity environment. There is still gravity in space - it is just a lot lower than on Earth. The shuttle orbits Earth at about 400 km above its surface where g=8.7 m/s^2, only slightly less than on Earth's surface. It is in fact gravity that causes the shuttle to orbit Earth. When in orbit around Earth, the shuttle is constantly falling around the planet. It never hits the ground because it is moving forward and its fall follows the curve of the Earth. In the diagram to the top right, the dashed line represents the shuttle's orbit around Earth. The solid lines show that if the shuttle does not reach the correct speed to stay in orbit, it will fall back to Earth. When it does reach the correct speed it will stay in orbit unless it slows down (which is what it does when it wants to land).



The reason the astronauts appear weightless is that they are falling freely towards Earth as they orbit around it. On Earth, the only way we sense weight is when something exerts a force back on us – the floor for example. On the shuttle everything, including the floor, is accelerating toward Earth together and there is no force exerted back on the astronauts. This is the sensation of **weightlessness**. This is why astronauts float around the space shuttle.

As you sit at rest in your chair, you feel the contact force (F_{norm}) balancing the non-contact force (F_{grav}).

A person in free fall does not experience any contact force and thus feels weightless.

The real effects of weightlessness are hard to reproduce on Earth. To simulate weightlessness astronauts are trained underwater, where **buoyancy** allows them to move like they were in outer space.

The aircraft used in training astronauts, nicknamed the "Vomit Comet", also simulates weightlessness when it goes into **free fall**.

It climbs to about 9800 m and then free falls to 7300 m. The astronauts experience weightlessness for about 25 s (Nowikow, et al., 2002). This is repeated up to as many as forty times. In space however, the astronauts would experience weightlessness as long as they were in orbit. NASA also runs a program to take students up on the Vomit Comet to experience weightlessness. These students do about 20 trials.

The effect of weightlessness on the human body is that body fluids will move towards the head. On Earth where gravity is present, fluids are normally drawn downward towards our feet. The upward motion of fluid actually begins on the launch pad. The following picture (Space Physiology) shows the usual position for astronauts at launch time, with their head back and legs and feet inclined upward.

One of the reasons for this launch position is so that the astronauts do not pass out during takeoff. Blackouts occur when blood drains from the head and goes to the lower parts of the body. Astronauts experience high accelerations during takeoff (about 98 m/s^2). At that acceleration, if they were standing or seated upright, the blood flow from the head would be so great that they could faint. While they are lying down during launch, the fluids in their bodies are already beginning to spread out. As fluids move upward because of gravity the body will respond by trying to eliminate what it detects as a flood of fluid in the chest (Space Physiology). Part of the body's response is a feeling of needing to go to the bathroom. This is why astronauts must wear a diaper during launch. They can actually lose up to about a litre of urine.

Once they are in space, astronauts' bodies undergo other changes because of the upward fluid movement. Since fluids are no longer being pulled downward, the heart does not have to work as hard in pumping blood, and therefore shrinks in size. This reduces how much blood is being pumped at any time. Also since the bones are no longer needed to support the astronaut against gravity, less bone tissue is produced and the bones weaken. Astronauts would also notice that their height increases by two to three centimetres or more, since gravity is no longer pushing down on them.

Conclusion

Becoming an astronaut requires big dreams and a commitment to making those dreams a reality. Part of that reality is an understanding of some physics concepts like gravity.

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Questions

1. An object is dropped on Earth and falls at 9.8 m/s^2. How fast will it be travelling after 1.0 s? After 2.0 s?
2. Why are astronauts placed in a horizontal launch position?
3. What are two effects of weightlessness on the human body?
4. **Research:** Why do the faces of astronauts appear puffy?
5. **Research:** How do astronauts go to the bathroom in space?

Activities

1. Tie a string to the top of a spring scale. Hang a 1.0 kg mass on the spring scale. Holding the scale in your hand, observe the weight of the mass. Then drop the scale and mass combination and observe the scale reading.

   Note to teacher: The reading on the falling spring scale will be 0 because the mass is accelerating downward with the scale and is in apparent weightlessness. (Zitzewitz, 1999)
2. Research how feelings of weightlessness might occur at an amusement park.
3. Use a pencil to poke a hole in the bottom and side of a cup. Hold your fingers over the two holes as you pour colored water into the cup until it is 2/3 full. Predict what will happen as the cup is allowed to fall. Drop the cup and watch closely.

   Note to teacher: Most students will predict that the water will run out of the bottom opening. Some students will believe that the water will run out of the bottom but not the side opening. When the cup is dropped the water stays in the cup. There is no pressure between the falling cup and the water inside it. Both the cup and the water are being accelerated the same by gravity. The water and cup are in apparent weightlessness. (Zitzewitz, 1999)
4. Like an astronaut, you can actually become taller but without having to go to space. Did you know that you are actually taller in the morning than you are at night? Try this. Before you go to bed reach for an object you can't quite touch. Go to bed. When you wake up try again to touch the object. You will have no problem clamping right onto it.